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Valuation of R&D and Advertising Expenditures

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Abstract：The purpose of the paper is to understand the role that uncertainty plays in determining the effect of R&D and advertising expenditures on market values. Real option literatures indicate that the investment on R&D or advertising can be viewed as purchase of growth options for firms. The cost of the investment is interpreted as the premium of the option. The growth option will be exercised only under favorable market outcome and thus has non-linear payoffs. Because of the convexity of the growth option, the value of the option increases with uncertainty in the market that a firm faces. In other words, the capitalization of R&D and advertising expenditures will be larger if there is higher uncertainty in the product market.

The role uncertainty plays in determining the valuation of R&D and advertising expenditures is explored using different sets of sample through regression analysis and robust OLS estimation. Empirical evidences indicate that firms facing more uncertainty in the market tend to invest more in R&D projects but not in advertising expenditure. Managers realize growth option features of R&D projects and make more investments to capture the benefit of uncertainty for the value of R&D projects. The option analogy for R&D investment may well explain high P/E ratios for high-tech or start-up firms, which have large R&D investments and face higher uncertainty. On the other hand, it seems that uncertainty does not play an important role in determining the effect of advertising expenditure on market value, which means that investors may not view advertising investments as a growth options. Finally, findings in event study indicate that the abnormal returns over the

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announcements of new R&D projects increase when there is larger uncertainty in the market. This again confirms the conjecture that R&D investment is considered as purchase of a growth option and therefore the value of the investment is positive correlated to volatility.

Key words：Real Options、R&D、Intangible Assets、Market Capitalization、Valuation

I. Introduction

It is not well understood why P/E ratio varies among firms. In some cases, the P/E ratios of high-tech firms are so large that the growth rates in traditional valuation to justify the stock prices are not sustainable. Some start-up firms, moreover, have none or negative earnings while the stock prices remains high. Traditional valuation methods in corporate finance fail to explain the phenomenon. A reasonable conjecture is that there might be some capitalization of intangible assets that is not carefully measured contained in the market value or that the existing consideration of capitalization may not tell the whole story. To analyze the variation of P/E ratio among different types of firms, the sources of firm values must be thoroughly examined.

Chan, Martin, and Kensinger (1990) study share-price responses to ninety-five announcements of increased R&D spending and find that the abnormal return is positive on average for high-tech firms and negative for low-tech firms. They also discover, in their cross-sectional analyses, that higher R&D intensity than the industry average leads to larger stock-price increases for high-tech firms. Similarly, Doukas and Switzer (1992) explore the event study of R&D increase announcement and reveal statistically positive R&D announcement abnormal returns, especially in the case of large high-tech industrial firms that devote substantial resources to R&D. In addition, Hall (1993) surveys the capitalization of R&D and advertising expenditure of publicly traded firms in the U.S. manufacturing sector during 1973-1991. He shows that the effects of the two intangible assets, R&D and advertising expenditures, are consistently positive and significant over time. Furthermore, he reports that although intangible R&D assets from 1973 through about 1983-1984 were about equally valued with tangible capital, the relationship broke down completely during the mid-1980's, with the R&D stock coefficient falling by a factor of 3 or 4. Besides, Chauvin and Hirschey (1993) provide evidence that advertising and R&D expenditures have large, positive and consistent influences on the market value of the firm by using COMPUSTAT data set during 1988-1990. Moreover, consistent with R&D event study

results by Chan, Martin, and Kensinger (1990) and Doukas and Switzer (1992), size advantage exist in advertising and R&D activity; the market value effect of a dollar in these types of expenditures tends to be greater for relatively larger firms. On the other hand, Zantout and Tsetsekos (1994) examine the effect of announcements of plans to increase R&D expenditures on the stock price of rival firms and find the empirical results to support the first-to-innovate hypothesis that rival firms suffer a statistically significant negative abnormal return at announcement. Finally, Szewczyk, Tsetsekos, and Zantout (1996) analyze the role of investment opportunities and free cash flow in explaining R&D-induced abnormal returns. After controlling for firm size, financial leverage, dividend yield, ownership structure, and industry structure, they find a significant positive relation between a firm's Tobin's Q and its price reaction to announcements of increases in R&D expenditures.

The positive share-price reaction to announcements of R&D spending discovered by previous studies can be taken as evidence of a strong link between R&D spending and the market value of the firm. Since spending on R&D and advertising can be viewed as a form of investment in intangible assets with predictably positive effects on future cash flows, the way in which the effect enters the firm's valuation function may illuminate the puzzle of P/E ratio variations. In fact, firm values can be considered as the result after firms solve the dynamic programming problem of choosing investment strategies to maximize the expected present discounted value of cash flow given a portfolio of stocks of capital assets. If firms cannot adjust the allocation of assets free of cost, the current portfolio of assets owned matters in determining the value of the optimal program conditional on the assets. In other words, the value of a firm can be express as a function of various stocks of capital in any given period. The value function of a firm is written as the sum of the composite physical capital and the intangible stocks. The most two important intangible assets are the R&D capital, which represents the value of future growth, and advertising expenditure, which represents the value of the brand names, product differentiation, and goodwill arising from product reputation.

The purpose of the paper is to understand the role that uncertainty plays in determining the effect of R&D and advertising expenditures on market values. Real option literatures indicate that the investment on R&D or advertising can be viewed as purchase of growth options for firms. The cost of the investment is interpreted as the premium of the option. The growth option will be exercised only under favorable market outcome and thus has non-linear payoffs. Because of the convexity of the growth option, the value of the option increases with uncertainty in the market that a firm faces. In other words, the capitalization of R&D and advertising expenditures will be larger if there is higher uncertainty in the product market that a firm faces. Kester (1984) and Pindyck (1991) suggest that growth options represent more than half of firm value if market volatility exceeds 20%. Growth option may explain the value of intangible assets such as R&D and advertising expenditures and justify, as a result, the high P/E ratios for high-tech or start-up firms.

The paper is organized as follows. Section II exhibits four-part empirical results: part A describes the features of top 20 R&D and advertising firms; part B analyzes the effect of volatility on capitalization of R&D and advertising in overall COMPUSTAT sample during 1997-1998; part C illustrates the volatility influence upon the effect of R&D and advertising on market values in computer and pharmaceutics industry during 1990-1998; part D explores the share-price reaction to the announcement of a new R&D project during 1995-1998. Section III concludes the article. In appendix, the valuation framework for a growth option is provided.

II. Empirical Investigation

A. Data Description

The sample is retrieved from COMPUSTAT annual database for 1996-1998 period with the criterion that the firm should have enough data for each variable in regressions specified in part B in COMPUSTAT. The final sample consists of 1542 observations for 1997 and 1503 for 1998.

Exhibit 1 shows the largest 20 R&D and advertising firms ranked in terms of R&D and advertising expenditures in 1997 and 1998. For R&D expenditure, the average R&D expense of $2.91 billion by the top 20 firms ranked by R&D expenditure is roughly 45 times greater than the $65.28 million dollar average R&D expense reported by all sample firms in 1997. And the average R&D expense of $3.31 billion by the top 20 firms is roughly 48 times greater than the $69 million dollar average R&D expense reported by all sample firms in 1998. For advertising expenditure, the average advertising expense of $1.84 billion by the top 20 advertising expenditure firms is roughly 52 times greater than the $35.48 million dollar average advertising expense reported by all sample firms in 1997. And the average advertising expense of $1.81 billion by the top 20 advertising expenditure firms is roughly 52 times greater than the $34.96 million dollar average advertising expense reported by all sample firms in 1998. Both R&D and advertising spending tend to be relatively concentrated among top firms. The top 20 R&D and advertising expenditure firms respectively account around 58% and 63% of total R&D and advertising expenditures for overall sample firms.

Not only do the top 20 R&D and advertising expenditure firms consistently account for a substantial share of the total R&D and advertising expenditure, similar group of top firms is found at the list of R&D and advertising expenditures year after year. General Motors, Ford, IBM, and Daimlerchrysler regularly appear as leaders in terms of R&D spending. General Motors, Procter & Gamble, Sony, and Philip Morris are perennial leaders in terms of advertising spending. This may suggest economies of scale effect on R&D and advertising investment.

In addition, the weighted-average [1] P/E ratio for the top 20 R&D expenditure firms is 16.07 (excluding negative P/E ratios) in 1997 and 23.99 in 1998. The weighted-average P/E ratio for the top 20 advertising expenditure firms is 15.22 (excluding one outliner) in 1997 and 20.76 in 1998. For the overall sample, the average P/E ratio is 34 in 1997 and 30 in 1998. The

[1] Weighted-average P/E ratio is calculated by using total asset value as weights.

weighted-average P/E ratios for the top 20 R&D and advertising expenditure firms, however, are not statistically[2] different from that for the overall sample.

Exhibit 2 shows the largest 20 R&D and advertising firms ranked in terms of the R&D and advertising intensities in 1997 and 1998. The R&D and advertising intensities are calculated by dividing R&D and advertising expenses, respectively, with total asset value. For R&D intensity, the average R&D intensity of 62.58% by the top 20 firms ranked by R&D intensity is roughly 20 times greater than the 3.14% average R&D intensity reported by all sample firms in 1997. And the average R&D intensity of 77.83% by the top 20 firms is roughly 23 times greater than the 3.39% average reported by all sample firms in 1998[3]. For advertising intensity, the average advertising intensity of 33% by the top 20 firms ranked by advertising intensity is roughly 28 times greater than the 1.18% average advertising intensity reported by all sample firms in 1997. And the average advertising intensity of 27.34% by the top 20 firms is roughly 24 times greater than the 1.15% average reported by all sample firms in 1998. Both R&D and advertising intensities are much higher among top firms. Besides, unlike the preliminary results in Exhibit 1, the groups of top firms at the list of R&D and advertising intensity vary a lot over year.

Furthermore, the weighted-average P/E ratio for the top 20 R&D intensity firms is 96.86 (excluding all negative P/E ratios) in 1997 and 573.94 in 1998. The weighted-average P/E ratio for the top 20 advertising intensity firms is 27.84 (excluding negative P/E ratios) in 1997 and 54.64 in 1998. Although the weighted-average P/E ratios for the top 20 advertising intensity firms are not statistically different from the one for the overall sample, the difference between the weighted-average P/E ratios for the top 20 R&D intensity firms and for the overall sample is significant at 0.05 level. The result indicates that

[2] T-test with 0.05 significant level.

[3] The average R&D intensity for the top 20 firms excluding the firms with ratio larger than 1 is 44%, around 14 times greater than the average reported by all sample firms, in 1997. The average R&D intensity for the top 20 firms excluding the firms with ratio larger than 1 is 33.27%, around 10 times greater than the average reported by all sample firms, in 1998.

high R&D intensity firms tend to have higher P/E ratios, which confirms the empirical results of investor's positive response to the announcements of R&D increases in most recent event studies. As mentioned before, the P/E ratios of those high R&D intensity firms are so large that the growth rates in traditional valuation to justify the stock prices are not sustainable. Moreover, negative earnings with high stock prices are not unusual for the high R&D intensity firms (top 20 R&D intensity firms in 1997 are good examples). The results seem to support the conjecture that it is the growth option created by R&D investment that makes the high R&D intensity firm so valuable.

Exhibit 1 The Top 20 Leading COMPUSTAT Firms in Terms of R&D and Advertising Expense

The Top 20 Firms in Terms of R&D Expense, 1997

Rank	DNUM	Company Name	Total Asset	Sales (MM)	R&D Expense	Advertising Expense	P/E
1	3711	GENERAL MOTORS CL H	228888	168738	4100	8200	6.98
2	3711	FORD MOTOR CO	279097	153627	2315	6327	8.45
3	7370	INTL BUSINESS MACHINES	81499	78508	1708	4307	16.93
4	3661	LUCENT TECHNOLOGIES IN	23811	26360	-	4047	95.09
5	3711	DAIMLERCHRYSLER AG	76204	68951	-	3148	8.33
6	3570	HEWLETT-PACKARD CO	31749	42895	1131	3078	21.14
7	2820	DU PONT (E I) DE NEMOU	42942	39911	-	2594	28.33
8	3663	ERICSSON (L M) TEL -A	18562.7	21246.51	-	2453.16	23.92
9	3651	SONY CORP -AMER SHARE	48507.9	51177.96	2037.77	2409.42	21.45
10	3674	INTEL CORP	28880	25070	1203	2347	16.53
11	3711	HONDA MOTOR LTD -AM S	36451.67	45418.15	1467.94	2163.99	18.24
12	2834	JOHNSON & JOHNSON	21453	22629	1260	2140	26.67
13	4813	BCE INC	28208.6	23233.7	-	2037.7	22.51
14	3600	KONINKLIJKE PHLPS ELC	29310.36	37698.97	-	2000.51	13.01
15	2834	PFIZER INC	15336	12504	948	1928	42.36
16	7372	MICROSOFT CORP	14387	11358	-	1925	49.14
17	3721	BOEING CO	38024	45800	-	1924	*
18	2834	GLAXO WELLCOME PLC -S	13921	13435	-	1883	28.00
19	2800	RHONE-POULENC SA -ADR	27381.42	14941.53	-	1685.25	*
20	2834	MERCK & CO	25811.9	23636.9	-	1683.7	27.68

The Top 20 Firms in Terms of R&D Expense, 1998

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Expense	Advertising Expense	P/E
1	3711	GENERAL MOTORS CL H	257389	158514	3700	7900	16.80
2	3711	FORD MOTOR CO	237545	144416	2200	6300	3.23
3	3711	DAIMLERCHRYSLER AG	159738	154615	-	5833	15.88
4	3661	LUCENT TECHNOLOGIES IN	26720	30147	-	5094	148.6
5	7370	INTL BUSINESS MACHINES	86100	81667	1681	4466	27.31
6	3570	HEWLETT-PACKARD CO	33673	47061	1214	3355	23.97
7	3651	SONY CORP -AMER SHARE	52492.11	56621.83	2627.58	3127.62	19.78
8	3663	ERICSSON (L M) TEL -A	20664.07	22854.05	-	3108.32	28.84
9	2834	MERCK & CO	31853.4	26898.2	-	2860.6	33.45
10	2820	DU PONT (E I) DE NEMOU	38536	24899	-	2751	36.59
11	3674	INTEL CORP	31471	26273	1300	2674	32.57
12	7372	MICROSOFT CORP	22357	14484	-	2502	75.79
13	2834	JOHNSON & JOHNSON	26211	23657	1190	2433	36.95
14	3600	KONINKLIJKE PHLPS ELC	33055.45	35762.6	-	2404.53	38.46
15	2834	PFIZER INC	18302	13544	1139	2279	81.17
16	2834	GLAXO WELLCOME PLC -S	15514	13536	-	1931	41.12
17	4813	BCE INC	20859.63	17856.08	-	1899.17	8.25
18	3721	BOEING CO	36672	56154	-	1895	28.13
19	2834	LILLY (ELI) & CO	12595.5	9236.8	-	1738.9	46.53
20	2834	AMERICAN HOME PRODUCTS	21079.07	13462.69	-	1654.75	29.99

The Top 20 Firms in Terms of Advertising Expense, 1997

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Expense	Advertising Expense	P/E
1	3711	GENERAL MOTORS CL H	228888	168738	4100	8200	6.98
2	2840	PROCTER & GAMBLE CO	27544	35764	3468	1282	32.78
3	2111	PHILIP MORRIS COS INC	55947	56114	3451	533	17.34
4	3711	FORD MOTOR CO	279097	153627	2315	6327	8.45
5	2834	BRISTOL MYERS SQUIBB	14977	16701	2241	1385	29.39
6	3651	SONY CORP -AMER SHARE	48507.9	51177.96	2037.77	2409.42	21.45
7	4813	AT&T CORP	58635	51319	1985	829	22.30
8	2080	PEPSICO INC	20101	20917	1800	-	36.99
9	7370	INTL BUSINESS MACHINES	81499	78508	1708	4307	16.93
10	3420	GILLETTE CO	10864	10062	1701	212	39.39
11	2080	COCA-COLA CO	16940	18868	1576	-	39.93
12	3711	HONDA MOTOR LTD -AM S	36451.67	45418.15	1467.94	2163.99	18.24
13	5311	SEARS ROEBUCK & CO	38700	41296	1330	-	14.93
14	2834	JOHNSON & JOHNSON	21453	22629	1260	2140	26.67
15	3674	INTEL CORP	28880	25070	1203	2347	16.53
16	3570	HEWLETT-PACKARD CO	31749	42895	1131	3078	21.14
17	3021	NIKE INC -CL B	5397.4	9553.1	1130	106.7	28.31
18	3861	EASTMAN KODAK CO	13145	14538	988	1230	6056
19	5311	PENNEY (J C) CO	23493	31219	977	-	28.32
20	2844	LAUDER ESTEE COS INC	1873.1	3381.6	976.2	35.3	35.23

The Top 20 Firms in Terms of Advertising Expense, 1998

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Expense	Advertising Expense	P/E
1	2840	PROCTER & GAMBLE CO	30966	37154	3704	1546	33.33
2	3711	GENERAL MOTORS CL H	257389	158514	3700	7900	16.80
3	3651	SONY CORP -AMER SHARE	52492.11	56621.83	2627.58	3127.62	19.78
4	2111	PHILIP MORRIS COS INC	59920	57813	2416	506	24.21
5	2834	BRISTOL MYERS SQUIBB	16272	18284	2312	1577	42.35
6	3711	FORD MOTOR CO	237545	144416	2200	6300	3.23
7	4813	AT&T CORP	59550	53223	1920	662	25.85
8	2080	PEPSICO INC	22660	22348	1900	-	30.28
9	3420	GILLETTE CO	11902	10056	1778	209	49.80
10	7370	INTL BUSINESS MACHINES	86100	81667	1681	4466	27.31
11	5311	SEARS ROEBUCK & CO	37675	41322	1670	-	15.40
12	2080	COCA-COLA CO	19145	18813	1597	-	46.85
13	3674	INTEL CORP	31471	26273	1300	2674	32.57
14	3570	HEWLETT-PACKARD CO	33673	47061	1214	3355	23.97
15	2834	JOHNSON & JOHNSON	26211	23657	1190	2433	36.95
16	2834	PFIZER INC	18302	13544	1139	2279	81.17
17	5311	PENNEY (J C) CO	23638	31380	1077	-	21.31
18	2844	LAUDER ESTEE COS INC	2512.8	3618	1027.8	43.5	47.50
19	2731	READERS DIGEST ASSN -	1564	2633.7	927	-	157.4
20	2834	WARNER-LAMBERT CO	9230.6	10213.7	904.4	877.2	49.14

Note: " - " denotes unavailable figure (data is not available)
" * " denotes negative figure

Exhibit 2 The Top 20 Leading COMPUSTAT Firms in Terms of R&D and Advertising Intensity

The Top 20 Firms in Terms of R&D Intensity, 1997

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Intensity	Advertising Intensity	P/E
1	6794	MIPS TECHNOLOGIES INC	19.67	40.31	3.4992	-	-
2	2835	MILLENNIUM PHARMACTCLS	144.51	89.93	1.0977	-	*
3	2834	ICOS CORPORATION	54.07	31.58	0.7912	-	*
4	7374	CSG SYSTEMS INTL INC	179.79	171.8	0.7123	-	*
5	7372	AXENT TECHNOLOGIES INC	56.48	44.64	0.6379	-	*
6	7372	VIASOFT INC	64.6	85.31	0.5395	-	*
7	3674	HI/FN INC	5.9	14.23	0.5068	-	-
8	2836	IMMUNEX CORP	227.33	185.3	0.4808	-	*
9	3559	NOVELLUS SYSTEMS INC	493.3	534	0.4238	0.0065	*
10	7372	VERITY INC	41.45	38.86	0.3749	-	*
11	7372	BANYAN SYSTEMS INC	42.93	74.34	0.3706	-	*
12	3576	VIDEOSERVER INC	72.9	53.5	0.3689	-	*
13	3576	VIDEOSERVER INC	66.31211	52.61702	0.3678	-	*
14	7370	INCYTE PHARMACEUTICALS	193.09	88.35	0.3570	0.0040	95.74
15	6794	INTERDIGITAL COMMUN CO	69.36	49.84	0.3496	-	*
16	3661	APPLIED INNOVATION INC	37.71	46.66	0.3421	-	*
17	7372	AVANT CORP	212.22	147.35	0.3334	-	67.00
18	3674	BROADCOM CORP -CL A	45.24	36.96	0.3316	-	-
19	7372	AVT CORP	54.41	58.09	0.3260	-	217.3
20	2836	IDEC PHARMACEUTICALS C	106.01	48.96	0.3057	-	*

The Top 20 Firms in Terms of R&D Intensity, 1997

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Intensity	Advertising Intensity	P/E
1	6794	MIPS TECHNOLOGIES INC	4.7	56.81	9.2447	-	3200
2	2834	ICOS CORPORATION	113.35	110.77	0.6791	-	38.14
3	7370	INCYTE PHARMACEUTICALS	230.29	134.81	0.4697	0.0047	287.5
4	2835	MILLENNIUM PHARMACTCLS	257.95	133.68	0.4427	-	76.10
5	3661	BROOKTROUT INC	73.21	100.85	0.4356	-	570.8
6	2836	IMMUNEX CORP	325.33	243.45	0.3687	-	6290
7	3674	HI/FN INC	16.61	21.53	0.3251	-	67.50
8	3661	APPLIED INNOVATION INC	39.77	53.63	0.3012	-	22.92
9	3576	DIALOGIC CORP	216.98	293.53	0.3012	-	8.58
10	7372	MIDWAY GAMES INC	227.42	391.23	0.2967	0.0999	10.00
11	7372	INFINIUM SOFTWARE INC	106.42	114.38	0.2844	-	312.5
12	7372	PHOENIX TECHNOLOGIES L	159.1	122.89	0.2811	-	287.5
13	3674	ZORAN CORP	49.17	44.23	0.2756	-	194.4
14	7372	ELECTRONIC ARTS INC	901.87	1221.86	0.2730	0.0803	46.77
15	7372	ADOBE SYSTEMS INC	767.33	894.79	0.2702	-	29.59
16	7372	SANCHEZ COMPUTER ASSOC	43.29	44.06	0.2693	-	47.95
17	7372	DELTEK SYSTEMS INC	66.31	83.07	0.2641	-	25.57
18	2834	NEXSTAR PHARMACEUTICAL	190.13	118.55	0.2623	-	23.72
19	7372	I2 TECHNOLOGIES INC	339.22	361.92	0.2619	-	104.7
20	7372	SUMMIT DESIGN INC	50.21	43.6	0.2597	-	27.39

The Top 20 Firms in Terms of Advertising Intensity, 1997

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Intensity	Advertising Intensity	P/E
1	2731	READERS DIGEST ASSN -	1643.8	2839	-	0.5736	19.05
2	5961	LANDS END INC	433.47	1263.63	0.0000	0.5230	17.44
3	2844	LAUDER ESTEE COS INC	1873.1	3381.6	0.0188	0.5212	35.23
4	2510	SELECT COMFORT CORP	57.24	184.43	0.0318	0.4941	-
5	5961	BRYLANE INC	720.2	1314.84	-	0.4196	17.91
6	2840	DIAL CORPORATION	883.85	1362.61	0.0139	0.3523	22.87
7	2040	RALCORP HOLDINGS INC	400.3	739.7	0.0097	0.3462	1.05
8	5961	VALUEVISION INTL INC	134.76	217.98	-	0.3331	6.69
9	2111	BROOKE GROUP LTD	126.46	301.93	-	0.3205	*
10	2082	BOSTON BEER INC -CL A	105.4	183.79	-	0.3176	21.11
11	2834	CHATTEM INC	178.74	143.24	0.0068	0.2953	18.44
12	5940	SHARPER IMAGE CORP	78.66	216.82	-	0.2899	60.71
13	2721	PLAYBOY ENTERPRISES -	175.54	296.62	-	0.2649	14.94
14	2082	COORS (ADOLPH) -CL B	1412.08	1822.15	0.0103	0.2549	15.05
15	3842	CNS INC	88.5	66.96	0.0125	0.2391	14.54
16	5961	SPIEGEL INC -CL A	1949.55	2981.69	0.0000	0.2330	*
17	3021	NIKE INC -CL B	5397.4	9553.1	0.0198	0.2094	28.31
18	2060	WRIGLEY (WM) JR CO	1343.13	1937.02	-	0.2082	34.00
19	3942	MATTEL INC	3803.79	4834.62	0.0411	0.2048	38.80
20	2060	HERSHEY FOODS CORP	3291.24	4302.24	0.0084	0.1987	27.53

The Top 20 Firms in Terms of Advertising Intensity, 1998

Rank	DNUM	Company Name	Total Asset (MM)	Sales (MM)	R&D Intensity	Advertising Intensity	P/E
1	2731	READERS DIGEST ASSN -	1564	2633.7	-	0.5927	157.4
2	5961	LANDS END INC	455.92	1371.38	0.0000	0.5766	26.41
3	2844	LAUDER ESTEE COS INC	2512.8	3618	0.0173	0.4090	47.50
4	5940	SHARPER IMAGE CORP	82.05	243.11	-	0.3339	21.99
5	2840	DIAL CORPORATION	1175.38	1524.52	0.0087	0.3176	27.76
6	2510	SELECT COMFORT CORP	106.23	246.27	0.0154	0.2979	24.26
7	2082	BOSTON BEER INC -CL A	122.69	183.45	-	0.2853	21.79
8	2082	COORS (ADOLPH) -CL B	1460.6	1899.53	0.0104	0.2710	30.18
9	2721	PLAYBOY ENTERPRISES -	212.11	317.62	-	0.2334	99.70
10	5961	VALUEVISION INTL INC	141.77	203.73	-	0.2238	39.06
11	2834	CHATTEM INC	369.01	220.06	0.0037	0.2165	24.81
12	5961	SPIEGEL INC -CL A	1857.26	2890.08	0.0000	0.2095	191.7
13	2111	BROOKE GROUP LTD	228.98	361.95	-	0.1945	20.48
14	2060	HERSHEY FOODS CORP	3404.1	4435.62	0.0084	0.1931	26.13
15	2060	WRIGLEY (WM) JR CO	1520.86	2004.72	-	0.1916	34.05
16	3942	MATTEL INC	4262.17	4781.89	0.0418	0.1908	21.17
17	2834	QUIGLEY CORP	48.61	36.35	0.0053	0.1897	10.85
18	3842	CNS INC	84.96	53.62	0.0240	0.1857	21.49
19	2844	CARTER-WALLACE INC	721.95	668.87	0.0358	0.1824	31.75
20	2090	WORTHINGTON FOODS INC	120.95	139.49	0.0138	0.1739	27.94

Note: " - " denotes unavailable figure (data is not available)
" * " denotes negative figure

B. Investigation for the Overall Sample

If growth option is indeed the reason that high R&D intensity firms maintain extraordinary P/E ratios, the effect of R&D investment on share prices should perform the behavior of growth options. In other words, the capitalization of growth options purchased with R&D spending will demonstrate the characteristics of growth options. More precisely, the effect of R&D investment on market firm values will be positive and increase with the volatility of the product market value to which the R&D projects are dedicated. Here the volatility of the stock price is assumed to be a good proxy for the volatility of the product market. The argument is that investors will adjust their valuation of a firm according to the expectation of a firm's operating outcomes so that stock price will reflect all the changes on product market value.

The overall sample used here is the same as the one described in part A and the groups are classified by the volatility of stock prices. The primary concern in this part is the role played by R&D and advertising as determinants

of the current market value of the firm. To isolate such influences, the effects of other factors that might affect current market value must be controlled. Two specifications of regressions are explored:

Regression 1: Market Value = α + β1*(Total Assets) + β2*(R&D Expense) + β3*(Advertising Expense) + β4*(Cash Flow) + β5*(Growth) + ε

Regression 2: Market Value = α + β1*(Total Assets) + β2*(R&D Intensity) + β3*(Advertising Intensity) + β4*(Cash Flow Ratio) + β5*(Growth) + ε

In regression 1, market value, total assets, R&D expense, and advertising expense are obtained by taking natural logarithm, respectively, of a firm's stock price times shares outstanding, total assets, R&D expense[4], and advertising expense in millions. Cash flow is measured by taking natural logarithm of two-year average net cash flow[5], and net cash flow is calculated by subtracting interest expense, taxes, preferred dividends, common dividends, R&D expense, and advertising expense from operating income before depreciation. Growth[6] is measure by the increment of natural logarithm sales in the year. In regression 2, market value, total assets and growth are measured in the same way as in regression 1. R&D intensity, advertising intensity, and cash flow ratio are obtained by dividing R&D expense, advertising expense, and net cash flow, respectively, with total assets. The stock price volatility, the classification variable, is retrieved from 30-day historical volatility database in CBOE.

[4] Hall (1986) shows that owing to the low variance of R&D series within a firm, the flow of R&D expenditure is a fairly good proxy for long-run R&D behavior. Hall (1993) also illustrates that the flow of R&D expenditure has more explanatory power for market value of a firm than the stock variable.

[5] Two-year net cash flow is considered as the best available indicator of a firm's ability to generate cash flows in the future.

[6] Miller and Modigliani (1961) argue that growth has a positive effect on the market value if future investments are expected to have abnormal return and if growth is an important determinant of the returns.

Exhibit 3 summarizes the means and standard deviations of important variables in each volatility group. R&D intensity averages increases[7] from low to medium volatility group and form medium to high volatility group in both years. Firms tend to invest more on R&D projects on average if there is more uncertainty in the markets, which supports the growth option argument from managers' points of view. However, advertising intensity averages do not share the same feature. Besides, the average cash flow ratios drop significantly from medium to high volatility group in both years. Average growth, as expected, increases with volatility group because growth firms are generally more volatile on their market values and more uncertain on product markets.

Exhibit 3 Summary Statistics in Each Volatility Group for COMPUSTAT Firms (Standard Deviation in Parentheses)

The Averages for COMPUSTAT Firms, 1997

Volatility Group	Volatility Average	R&D Intensity Average	Advertising Intensity Average	Cash Flow Ratio Average	Growth Average
Low	25.6585	0.01758	0.01220	0.05640	0.1390
	(5.6736)	(0.04342)	(0.04299)	(0.08314)	(0.2466)
Medium	40.8894	0.0238	0.01235	0.06478	0.2087
	(4.547)	(0.04587)	(0.04612)	(0.1032)	(0.3129)
High	72.389	0.05291	0.01078	0.02474	0.3381
	(28.566)	(0.1110)	(0.03261)	(0.2419)	(0.4719)

The Averages for COMPUSTAT Firms, 1998

Volatility Group	Volatility Average	R&D Intensity Average	Advertising Intensity Average	Cash Flow Ratio Average	Growth Average
Low	25.6012	0.01552	0.01065	0.055825	0.1010
	(5.6638)	(0.03272)	(0.0334)	(0.08977)	(0.2651)
Medium	40.9485	0.0238	0.01246	0.06756	0.1767
	(4.500)	(0.04539)	(0.04646)	(0.088)	(0.3197)
High	72.617	0.06243	0.01150	0.04143	0.2809
	(28.843)	(0.4180)	(0.03475)	(0.2414)	(0.3641)

Exhibit 4 shows the empirical results estimated through robust ordinary least squares (OLS) for regression 1 using overall sample. After controlling for other important valuation factors, the evidence in Exhibit 4 suggests that

[7] The increases between groups are statistically significant at 0.01 level.

the effects of R&D and advertising expenditures on market values are consistently positive and significant. Furthermore, the market value influence of R&D and advertising expenditure seems to depend upon volatility considerations. The coefficient of R&D expenditure for the medium volatility group is statistically larger than for the low volatility group in both years at 0.05 significant level. That is, for moderate volatility level, the effect of R&D expenditure increases with volatility groups in both 1997 and 1998. In other words, the positive effect of R&D expenditure on market value rises when there is greater uncertainty in the market that a firm faces. However, the difference between medium and high volatility groups is not significant for R&D expenditure influences in both years. There are many possible explanations for the result and further exploration is needed to better understand the features of the capitalization. Two possible explanations are: 1) The drawbacks of large uncertainty actually offset the benefits of option value increases, and 2) There may be mis-pricing in stock markets. One possible drawback is that large uncertainty increases the probability to abandon the R&D project halfway due to shortage of cash flows. On the other hand, the differences among volatility groups for the effects of advertising expenditure are not statistically significant in both years although the coefficient of advertising expenditure seems to decrease with volatility groups in 1997 and 1998.

Exhibit 5 illustrates the influence of volatility on R&D and advertising intensity effects on market values in regression 2 estimated through robust OLS for overall sample. The same control variables are applied to constrain other important effects while a different specification for cash flow is adopted in regression 2. Similar to the empirical results in Exhibit 4, the effects of R&D and advertising expenditures on market values are consistently positive and significant except the effect of advertising expenditure for high volatility firms in 1997 and 1998. The drawbacks of high uncertainty seem to play a more important role in determining the effects of R&D and advertising intensities. The coefficients of R&D intensity drop dramatically from medium

to high volatility group in both years. The increases in coefficients of R&D intensity is statistically significant at 0.05 level from low to medium volatility group in 1998 but not in 1997. In other words, the positive effect of R&D intensity on market values increases with uncertainty at moderate volatility level but decreases at high volatility level. On the other hand, the decreases in coefficients of advertising intensity is statistically significant at 0.05 level among volatility groups in both years except the difference between low and medium groups in 1998. That is, the positive effect of advertising intensity on market value falls when there is greater uncertainty in the market that a firm faces. While both R&D and advertising are considered most important intangible assets for a firm, it seems that the capitalization of advertising does not perform the analogy of a financial call option and decreases with risk-adjusted rate of return which increases with uncertainty.

Based on Exhibit 4 and Exhibit 5, the capitalization of R&D investments seems to demonstrate behavior analogous to a financial call option for moderate uncertainty. In other words, investors tend to value R&D projects in a firm as growth options and consider the option value as a part of the firm's market value. However, the capitalization of R&D investment for high uncertainty and that of advertising expenditure do not have this feature. It is probably because investors do not value advertising expenditure as a growth option and because the drawbacks of R&D investments in a highly uncertain market outweigh the benefit of uncertainty for an R&D project as a growth option. In the meantime, mis-pricing in stock markets also provides another possible explanation.

Exhibit 4 The Effects of R&D and Advertising Expenditure on the Market Value of the COMPUSTAT Firms in Regression 1:

Market Value = α + β1*(Total Assets) + β2*(R&D Expense) + β3*(Advertising Expense) + β4*(Cash Flow) + β5*(Growth) + ε

(t-Statistics in Parentheses)

The Effects on COMPUSTAT firms, 1997

Volatility Group	Intercept	Total Assets	R&D Expense	Advertising Expense	Cash Flow (Average)	Growth	R-square	F statistics	Sample Size
Low	2.531	0.578	0.029	0.037	0.242	0.185	0.8259	402**	430
	(14.6)**	(16.8)**	(6.41)**	(6.11)**	(7.36)**	(1.48)			
Medium	2.814	0.435	0.044	0.023	0.393	0.648	0.8247	399**	430
	(18.2)**	(13.4)**	(8.62)**	(3.7)**	(10.98)**	(5.88)**			
High	2.811	0.462	0.043	0.013	0.331	0.575	0.7648	275**	430
	(16.3)**	(11.9)**	(7.53)**	(1.85)*	(8.86)**	(6.32)**			
All	2.76	0.488	0.039	0.024	0.32	0.52	0.8239	1201**	1290
	(29.8)**	(24.4)**	(13.4)**	(6.59)**	(15.8)**	(8.63)**			

The Effects on COMPUSTAT firms, 1998

Volatility Group	Intercept	Total Assets	R&D Expense	Advertising Expense	Cash Flow (Average)	Growth	R-square	F statistics	Sample Size
Low	2.2343	0.5043	0.032	0.037	0.394	0.328	0.8059	350**	428
	(11.7)**	(12.3)**	(6.27)**	(5.7)**	(9.24)**	(2.44)**			
Medium	2.512	0.491	0.051	0.028	0.358	0.602	0.7520	256**	428
	(12.5)**	(11.7)**	(8.0)**	(3.69)**	(7.78)**	(3.62)**			
High	2.674	0.535	0.058	0.026	0.2403	0.515	0.6309	144**	428
	(11.2)**	(10.6)**	(8.2)**	(3.23)**	(5.3)**	(4.03)**			
All	2.48	0.519	0.047	0.029	0.319	0.481	0.7593	806**	1284
	(21.3)**	(20.7)**	(13.2)**	(6.85)**	(12.4)**	(5.96)**			

* Indicates statistical significance at the 0.05 level

** Indicates statistical significance at the 0.01 level

Exhibit 5 The Effects of R&D and Advertising Expenditure on the Market Value of the COMPUSTAT Firms in Regression 2:

Market Value = α + β1*(Total Assets) + β2*(R&D Intensity) + β3*(Advertising Intensity) + β4*(Cash Flow Ratio) + β5*(Growth) + ε

(t-Statistics in Parentheses)

The Effects on COMPUSTAT firms, 1997

Volatility Group	Intercept	Total Assets	R&D Intensity	Advertising Intensity	Cash Flow Ratio	Growth	R-square	F statistics	Sample Size
Low	0.5986 (3.85)**	0.8726 (48.9)**	7.7754 (11.1)**	6.735 (8.22)**	3.847 (9.6)**	0.1069 (0.949)	0.8275	488**	514
Medium	0.292 (0.736)	0.813 (46.2)**	8.456 (10.9)**	4.815 (6.64)**	2.79 (7.9)**	0.261 (2.6)**	0.8127	440**	514
High	1.531 (10.5)**	0.778 (35.9)**	2.43 (7.04)**	0.317 (0.33)	0.848 (5.15)**	0.515 (7.17)**	0.7290	273**	514
All	1.24 (14.8)**	0.815 (77.8)**	3.953 (13.9)**	3.1023 (6.88)**	1.376 (10.1)**	0.436 (8.44)**	0.8061	1277**	1542

The Effects on COMPUSTAT firms, 1998

Volatility Group	Intercept	Total Assets	R&D Intensity	Advertising Intensity	Cash Flow Ratio	Growth	R-square	F statistics	Sample Size
Low	0.0216 (0.119)	0.9286 (44.3)**	11.185 (10.9)**	8.2725 (7.95)**	3.4373 (8.7)**	-0.112 (-0.93)	0.8013	398**	501
Medium	-0.24 (-1.262)	0.9286 (43.7)**	13.51 (14.3)**	8.323 (9.32)**	6.053 (11.6)**	0.369 (3.34)**	0.7977	390**	501
High	1.992 (10.0)**	0.712 (23.8)**	0.425 (2.94)**	1.484 (1.224)	-0.227 (-0.892)	0.463 (4.08)**	0.5342	114**	501
All	1.33 (12.5)**	0.806 (59.5)**	1.07 (8.33)**	3.456 (5.52)**	0.831 (4.1)**	0.327 (4.59)**	0.7073	723**	1503

* Indicates statistical significance at the 0.05 level

** Indicates statistical significance at the 0.01 level

C. Industry Examination

More than 60% of the top 20 R&D expenditure or R&D intensity firms belongs to computer and pharmaceutics industry. Computer industry here is defined as firms with SIC codes from 7370 to 7377 while pharmaceutics industry is defined as those from 2833 to 2836. Two industry samples are obtained from COMPUSTAT during 1990-1998 with the criterion that the firm should have enough data for each variable in regressions.

Exhibit 6 summaries means and standard deviations of important variables in each volatility group for both industries. The R&D intensity in each volatility group for both industries on average is larger than that for overall COPUSTAT firms. The increases in average R&D intensity from low to medium and from medium to high volatility group are statistically significant at 0.01 level in both industries except the increase from low to medium volatility group in pharmaceutics industry. Firms facing higher uncertainty tend to invest more in R&D to take the advantage of nonlinear payoff feature of growth options. Advertising intensity average, however, seems to decrease with volatility group although t-statistics are not significant. Average cash flow ratio drops dramatically while uncertainty in the market increases. Average growth, as before, has positive correlation with volatility level.

Exhibit 6 Summary Statistics in Each Volatility Group for Computer Industry and Pharmaceutics Industry, 1990-1998, (Standard Deviation in Parentheses)

The Averages for Computer Industry

Volatility Group	Volatility Average	R&D Intensity Average	Advertising Intensity Average	Cash Flow Ratio Average	Growth Average
Low	36.009	0.09187	0.00792	0.09406	0.1762
	(7.4335)	(0.1119)	(0.03041)	(0.5076)	(0.7143)
Medium	55.881	0.1107	0.01101	0.06371	0.2706
	(3.487)	(0.09995)	(0.02944)	(0.3322)	(0.598)
High	82.45	0.1395	0.01799	-0.006065	0.3551
	(25.172)	(0.1086)	(0.04449)	(0.2315)	(0.6831)

The Averages for Pharmaceutics Industry

Volatility Group	Volatility Average	R&D Intensity Average	Advertising Intensity Average	Cash Flow Ratio Average	Growth Average
Low	27.7677	0.1031	0.03505	0.02631	0.1648
	(5.322)	(0.0676)	(0.05785)	(0.1769)	(0.3035)
Medium	42.449	0.1081	0.01215	0.02844	0.2789
	(5.4354)	(0.09087)	(0.0322)	(0.1796)	(0.5098)
High	68.464	0.1559	0.02759	-0.1444	0.3848
	(14.576)	(0.2370)	(0.07942)	(0.3272)	(0.7404)

Similar to the specifications of regression in part B, two equations are set up to explore the effects of R&D and advertising on market value in two industries during 1990-1998:

Regression 3: Market Value = α + β1*(Total Assets) + β2*(R&D Expense) + β3*(Advertising Expense) + β4*(Cash Flow) + β5*(Growth) + β6*(Year) + ε

Regression 4: Market Value = α + β1*(Total Assets) + β2*(R&D Intensity) + β3*(Advertising Intensity) + β4*(Cash Flow Ratio) + β5*(Growth) + β6*(Year) + ε

The only difference between regression 1 and regression 3 is that there is one more variable, year, added to regression 3. And it is the same difference between regression 2 and regression 4. The dummy variable, year, is assigned 1 if the year of the data is 1990, 2 if the year of the data is 1991, 3 if 1992, and so on. The classification variable, the volatility index, is taken as the average of 30-day historical volatility at the end of 1997 and 1998[8]. The coefficients estimated for regression 3 and regression 4 are interpreted as the average effects of the independent variables over the nine sampling years.

Exhibit 7 shows the effects of R&D and advertising expense on market value estimated through robust OLS for regression 3. After controlling other important influences on market value, the effects of R&D and advertising expense are consistently positive and significant (except the effect of advertising

[8] Here the assumption is that the volatility of a firm's stock price does not change so dramatically that a firm switches groups in these ten years.

expense in medium and high volatility groups for pharmaceutics industry), which is similar to the empirical results in part B. Furthermore, the coefficient of R&D expense in both industries increases from low to medium volatility group and decreases from medium to high volatility group[9], which is also similar to the results in part B. The effect of R&D expense on market value depends on volatility consideration and the positive effect increases with uncertainty for moderate volatility level. The drawbacks of uncertainty, however, reduce the positive effect of R&D expense for high volatility level. On the other hand, there is no significant difference among coefficients of advertising expense in three volatility groups for both industries. It seems that uncertainty does not play an important role in determining the effect of advertising expense on market value in computer and pharmaceutics industry. Besides, advertising expense seems not to be an important factor to affect market value in pharmaceutics industry. This might due to industry-specific features of pharmaceutics industry.

Exhibit 8 illustrates the influence of volatility on R&D and advertising intensity effects on market values for computer and pharmaceutics industry in regression 4 through robust OLS estimation. In these two industries, the effect of R&D intensity in both low and medium volatility groups is significantly positive and, although the coefficients for low and medium volatility groups are not statistically different, the effect tends to increase with volatility. In addition, the coefficient of R&D intensity in high volatility group is not significant for both industries, which means that the effect of R&D intensity on firms' market value may be zero when the market is very uncertain. The results are consistent with those above and indicate that the positive effect of R&D on market value increases with the extent of uncertainty for moderate volatility level and decreases for high volatility level. On the other hand, the coefficient of advertising intensity is significantly negative in low volatility group for computer industry and in medium and high volatility group for pharmaceutics industry. One of the possible explanations of the inconsistency is that advertising

[9] The increase from low to medium volatility group and the decrease from medium to high volatility group for computer industry are statistically significant at 0.01 level but not for pharmaceutics industry.

expenditure is probably capitalized as a growth option in computer industry but not in pharmaceutics industry. The effect of advertising intensity seems to behave in the same way as that of R&D intensity for computer industry – increases with uncertainty for moderate volatility level and decreases for high volatility level. However, the effect of advertising intensity for pharmaceutics industry behaves, as usual, as a normal asset and decreases with uncertainty.

Consistent with the empirical findings for overall COMPUSTAT firms in part B, the capitalization of R&D investment performs the analogy to a financial call option for moderate degree of uncertainty in both computer and pharmaceutics industry. In other words, R&D projects are treated as growth options with convex payoffs for a firm to exercise in the future if the market goes well. The analogy for the capitalization of advertising expenditure, however, is ambiguous for computer industry. Also, the capitalization of R&D investment for both industries does not have the feature when there is large uncertainty in the market. This, as indicated in the previous section, may result from mis-pricing in the stock market or from the drawbacks of high uncertainty. The justification for existence of mis-pricing in the stock market could come from the fact that high uncertainty also increases arbitrage risks, which deters arbitrageurs from bringing stock prices back to fundamental values[10]. In the meantime, there are still other possible explanations for the result and further exploration is needed to better understand the features of the capitalization. Generally speaking, the effect of R&D investment on market value displays the analogy of a call option for moderate uncertainty but not for high volatility level. Besides, the effect of advertising expenditure seems not to have the feature.

[10] De Long et al (1990) suggests that would-be arbitrageurs who take positions in a mis-priced stock, and hedge with opposite positions in imperfect substitute (because individual stocks do not, in practice, have perfect substitute), face the risk that two return streams do not cancel out. Risk averse arbitrageurs will trade less aggressively if they must bear arbitrage risk.

Exhibit 7 The Effects of R&D and Advertising Expenditure on the Market Value of Computer Industry and Pharmaceutics Industry in Regression 3, 1990-1998 (t-Statistics in Parentheses)

Market Value = α + β1*(Total Assets) + β2*(R&D Expense) + β3*(Advertising Expense) + β4*(Cash Flow) + β5*(Growth) + β6*(Year) + ε

The Effects on Computer Industry

Volatility Group	Intercept	Total Assets	R&D Expense	Advertising Expense	Cash Flow (Average)	Growth	Year	R-square	F statistics	Sample Size
Low	1.129	0.619	0.0278	0.035	0.2898	1.298	0.0659	0.8909	231.48**	177
	(3.77)**	(9.3)**	(3.012)**	(2.78)**	(5.174)**	(8.227)**	(2.982)**			
Medium	2.105	0.586	0.0685	0.0365	0.209	0.804	0.1176	0.7711	103.3**	191
	(6.576)**	(8.124)**	(7.01)**	(3.016)**	(3.94)**	(3.91)**	(5.391)**			
High	1.285	0.735	0.0389	0.0389	0.179	1.0904	0.0996	0.7814	98.28**	172
	(3.774)**	(8.61)**	(3.156)**	(2.971)**	(3.427)**	(6.063)**	(3.995)**			
All	1.576	0.628	0.0411	0.0289	0.2288	1.031	0.1018	0.8350	449.71**	540
	(8.924)**	(15.664)**	(7.254)**	(3.872)**	(7.232)**	(10.647)**	(7.725)**			

The Effects on Pharmaceutics Industry

Volatility Group	Intercept	Total Assets	R&D Expense	Advertising Expense	Cash Flow (Average)	Growth	Year	R-square	F statistics	Sample Size
Low	1.9448	0.6192	0.0287	0.0162	0.369	0.591	0.0673	0.9750	604.9**	100
	(7.68)**	(6.632)**	(2.894)**	(2.68)**	(8.707)**	(2.34)*	(4.235)**			
Medium	1.6383	0.6515	0.0375	0.0104	0.375	0.9197	-0.0205	0.9427	271.36**	106
	(5.10)**	(7.841)**	(3.294)**	(1.078)	(5.093)**	(2.71)**	(-0.941)			
High	1.411	0.8001	0.0242	0.0217	0.142	0.1235	0.0719	0.8539	88.64**	98
	(3.00)**	(6.27)**	(2.127)*	(1.286)	(1.245)	(0.732)	(1.955)*			
All	1.8033	0.6415	0.033	0.0107	0.3114	0.2836	0.0376	0.9266	624.44**	304
	(8.678)**	(12.016)**	(3.207)**	(1.697)*	(6.963)**	(2.538)**	(2.498)**			

* Indicates statistical significance at the 0.05 level

**Indicates statistical significance at the 0.01 level

Exhibit 8 The Effects of R&D and Advertising Intensity on the Market Value of Computer Industry and Pharmaceutics Industry in Regression 4, 1990-1998, (t-Statistics in Parentheses)

Market Value = α + β1*(Total Assets) + β2*(R&D Intensity) + β3*(Advertising Intensity) + β4*(Cash Flow Ratio) + β5*(Growth) + β6*(Year) + ε

The Effects on Computer Industry

Volatility Group	Intercept	Total Assets	R&D Intensity	Advertising Intensity	Cash Flow Ratio	Growth	Year	R-square	F statistics	Sample Size
Low	0.9077	0.8196	2.431	-4.565	0.4099	0.2904	0.1171	0.8142	203.83**	286
	(4.144)**	(30.57)**	(3.518)**	(-2.092)*	(3.091)**	(3.361)**	(6.241)**			
Medium	-0.2468	1.0246	2.7753	6.1146	0.987	0.8085	0.083	0.8246	227.3**	297
	(-1.31)	(31.893)**	(6.356)**	(4.067)**	(6.417)**	(10.05)**	(4.819)**			
High	0.8261	0.9378	0.1166	2.079	0.9475	0.3871	0.0775	0.7565	150.14**	297
	(4.393)**	(24.708)**	(0.283)	(2.417)*	(4.652)**	(6.571)**	(4.86)**			
All	0.775	0.861	1.4842	1.8536	0.6338	0.4518	0.1021	0.7917	553.1**	880
	(6.801)**	(51.987)**	(5.245)**	(2.35)*	(7.309)**	(10.074)**	(9.97)**			

The Effects on Pharmaceutics Industry

Volatility Group	Intercept	Total Assets	R&D Intensity	Advertising Intensity	Cash Flow Ratio	Growth	Year	R-square	F statistics	Sample Size
Low	0.725	0.9462	5.328	0.9138	1.7733	0.625	0.00616	0.9507	505.08**	164
	(3.724)**	(41.45)**	(6.871)**	(1.154)	(5.417)**	(4.583)**	(0.376)			
Medium	0.5638	0.9867	5.40	-5.7398	2.342	0.2067	0.0039	0.9098	247.15**	154
	(2.706)**	(31.91)**	(5.545)**	(-3.33)**	(4.656)**	(1.978)*	(0.187)			
High	1.0048	0.9181	0.7248	-7.7675	0.1536	0.1131	0.0475	0.8358	119.6**	168
	(4.165)**	(23.438)**	(1.703)	(-3.508)**	(0.483)	(1.345)	(1.837)*			
All	0.9293	0.9805	3.798	-3.197	0.8065	0.1683	0.0107	0.9133	806.22**	466
	(7.711)**	(58.457)**	(5.565)**	(-3.985)**	(3.839)**	(2.858)**	(0.846)			

* Indicates statistical significance at the 0.05 level

** Indicates statistical significance at the 0.01 level

D. Event Study

Since the capitalization of R&D investment demonstrates the analogy of a financial call option, the effect of new R&D project announcements on market value is expected to increase with uncertainty in the market that a firm faces. Viewing an R&D project as a growth option, investors may react to a firm's announcement according to the premium (cost of an option) and the value of the growth option. Besides, there are two hypotheses explaining different reactions of investors to the announcement of new investments. First, the investment opportunity hypothesis states that R&D investments by firms with promising growth opportunities are generally worthwhile, whereas those by firms with no growth opportunities may be wasteful. The other one, the free cash flow hypothesis, exclaims that managers will invest free cash flow in wasteful investments rather than pay it out to shareholders and hence the agency costs of R&D investments may be higher for high-free-cash-flow firms. On the other hand, R&D investments by low-free-cash-flow firms increase the probability for them to look for external financing, and the firm's willingness to undergo external monitoring may be a favorable signal.

The sample of new R&D project announcements is collected through reviewing the Wall Street Journal Index with the following screening criteria: 1) The announcement is an initial announcement of a future plan to start a new R&D project; 2) The news does not reveal different announcements at the same time; 3) The announcing firm has sufficient data on the CRSP; 4) The stock option of the firm is traded in the market. There are 43 announcements during January 1995 and December 1998 in the final sample. The regression adopted to explore the effect of volatility on abnormal returns is specified as following:

Regression 5: Abnormal Return = α + β1*(Free Cash Flow Ratio)
+ β2*(Tobin's Q)+β3*(Volatility) + ε

where

Free Cash Flow Ratio[11] = (Operating income before depreciation – Interest Expense –Taxes – Preferred Dividends – Common Dividends) / Total Assets

[11] The specification of free cash flow ratio is also adopted in previous research, e.g. Szewczyk, Tsetsekos, and Zantout (1996).

Tobin's Q[12] =(Stock Price * Shares Outstanding + Liquidating Value of Preferred Stock+ Short-term Liabilities – Short-term Assets + Long-term Debt) / Total Assets

The window of the event is four days and the abnormal return is obtained by subtracting four-day value-weighted market return from four-day stock return. The volatility is measured by implied volatility using Black-Schole formula and market stock option prices[13] on the announcement day.

The average abnormal four-day announcement-period stock return is 0.413%, which is significant at 0.1 level. Of the abnormal returns in the sample, around 60% are positive, which means that the result is not caused by outliers. Exhibit 9 illustrates the influence of market uncertainty on the reactions to new R&D project announcements through robust OLS estimation. The coefficient of volatility is statistically positive at 0.01 significant level. In other word, the abnormal returns over the announcements of new R&D projects increase when there is larger uncertainty in the market. R&D investment is considered as purchase of a growth option and therefore the value of the investment is positive correlated to volatility. Finally, although the coefficient of Tobin's Q is not statistically significant, the signs of the coefficients for free cash flow ratio and Tobin's Q are pretty the same as what expected. Firms of large Tobin's Q are more likely to have better growth opportunities and their investments would be more valuable. On the other hand, high free cash flow ratios may suggest agency problems between investors and managers so that investors would view them as bad signals and reduce the valuation of the investments.

Exhibit 9 The Effect of R&D project announcements on the Market Value, 1995-1998 (t-Statistics in Parentheses)

	Intercept	Free Cash Flow Ratio	Tobin's Q	Volatility	R-square	F statistics	SampleSize
Abnormal Return	0.34 (2.31)*	-0.33 (2.086)*	0.016 (1.679)	0.0083 (2.79)**	0.1927	2.92*	43

* Indicates statistical significance at the 0.05 level

** Indicates statistical significance at the 0.01 level

[12] See more detail about the approximation of Tobin's Q in Chung and Pruitt (1994).

[13] The stock option with the expiration date after but closest to the announcement day is referred.

III. Concluding Remarks

The value function of a firm is re-examined with focus on two important intangible assets, R&D and advertising, to understand high P/E ratios of start-up or high-tech companies. Positive effects of R&D and advertising expenditures on market values of firms are explored in the paper for different sets of samples. Empirical evidences indicate that firms facing more uncertainty in the market tend to invest more in R&D projects but not in advertising expenditure. Managers realize growth option features of R&D projects and make more investments to capture the benefit of uncertainty for the value of R&D projects. With unsymmetrical payoffs, R&D projects are more likely to have positive NPV and to be adopted if the uncertainty in the market is large.

On the other hand, the role uncertainty plays in determining the capitalization of R&D and advertising expenditures is analyzed to analogize R&D and advertising investments to growth options. Empirical results reported here suggest that the effect of R&D expenditure on market value depends on volatility consideration and the positive effect increases with uncertainty for moderate volatility level. The effect of R&D expenditure for high volatility level, however, does not exhibit this feature. There are many possible explanations for the result and further exploration is needed to justify each possible explanation. Two possible explanations are: 1) The drawbacks of large uncertainty actually offset the benefits of option value increases, and 2) There is mis-pricing[14] in stock markets. One of possible drawbacks is large probability of discarding R&D projects halfway owing to shortage of cash flows. As shown in summary statistics, firms facing high uncertainty have much lower and volatile cash flow ratios so that internal funding for R&D investment is pretty uncertain. R&D projects, however, are highly information sensitive, and firms will have a hard time raising external funding unless they are willing to share the information of

[14] As mentioned in the previous section, high uncertainty also increase the risk of arbitrage and deter risk-averse arbitrageurs from bringing stock prices back to fundamental values. Besides, as suggested in Shleifer and Vishny (1997), idiosyncratic risk of target stocks may deter arbitrage activity. In particular, some stocks with high idiosyncratic variance may be overpriced, but the overpricing is not eliminated by arbitrage because shorting those stocks is too risky.

their R&D projects with outside creditors. R&D project funding, therefore, mainly relies on internal capital and subjects to cash flow sufficiency.

The option analogy for R&D investment may well explain high P/E ratios for high-tech or start-up firms, which have large R&D investments and face higher uncertainty. On the other hand, it seems that uncertainty does not play an important role in determining the effect of advertising expenditure on market value, which means that investors may not view advertising investments as a growth options. Finally, findings in event study indicate that the abnormal returns over the announcements of new R&D projects increase when there is larger uncertainty in the market. This again confirms the conjecture that R&D investment is considered as purchase of a growth option and therefore the value of the investment is positive correlated to volatility.

Appendix: Valuation of Growth Options

A. Basic Model

Denote V as the value of the product market to which the R&D investment[15] is devoted, and C as the irreversible cost to enter the product market. A firm makes R&D investment I at time 0 and decides whether or not to pay a sunk cost C (entering the new product market) in return for V at time t. Assume I and C is constant while V evolves according Geometric Brownian Motion, which means that the current value of the product market is known but future values are log-normal distributed with a linearly increasing variance over time.

$$dV = \alpha V\, dt + \sigma V\, dz \qquad (1)$$

where α and σ are constant. Denote the value of the R&D investment (i.e. the value of the option to invest) as F(V). Maximize the expected present value by dynamic programming to get F(V):

$$F(V) = \max \quad E_0[(V_t - C)e^{-\eta t}] \qquad (2)$$

where E_0 is the expectation at time 0, t is the (unknown) future time that the irreversible investment C is made, η is the discount rate[16], and V is described in equation (1). Assume that $\eta > \alpha$, and denote $\delta = \eta - \alpha$.

If the R&D project yields no cash flows up to time t, the Bellman equation is:

$$\eta F(V)\, dt = E[dF(V)] \qquad (3)$$

Using Ito's Lemma to obtain the expression of dF from equation (1) and substituting $\delta = \eta - \alpha$, for infinite time horizon, equation (3) can be rewritten as a partial differential equation (PDE):

$$\frac{1}{2}\sigma^2 V^2 F_{VV} + (\eta - \delta)VF_V - \eta F = 0 \qquad (4)$$

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[15] The growth option model of valuing advertising investment can be obtained by the same derivation.

[16] If the market is complete so that stochastic changes in V are spanned by existing assets, the contingent claims approach can be adopted and the arbitrary discount rate η is not explicitly required (η is replaced by risk-free interest rate in PDE).

where F_V and F_{VV} are F's first and second derivatives with respect to V.

In addition, F(V) needs to satisfy the following boundary conditions:

$$F(0) = 0 \quad (5a) \qquad F(V^*) = V^* - C \quad (5b) \qquad F_V(V^*) = 1 \quad (5c)$$

Condition (5a) states that the option to invest will be of no value if the value of the product market equals zero[17]. V* is the level of the market value at which entrance is optimal, and condition (5b) says that upon entrance, the firm receives a net payoff (V* – C). Condition (5c) is called the "smooth pasting" condition. The value of the R&D investment, F(V), can be obtained by solving equation (4) subject to the boundary conditions (5a – 5c).

The general solution to equation (4) is:

$$F(V) = AV^{\beta_1} + BV^{\beta_2} \quad \text{where}$$

$$\beta_1 = \frac{1}{2} - \frac{\eta - \delta}{\sigma^2} + \left\{ \left[\frac{\eta - \delta}{\sigma^2} - \frac{1}{2} \right]^2 + \frac{2\eta}{\sigma^2} \right\}^{\frac{1}{2}} > 1 \quad \text{and}$$

$$\beta_2 = \frac{1}{2} - \frac{\eta - \delta}{\sigma^2} - \left\{ \left[\frac{\eta - \delta}{\sigma^2} - \frac{1}{2} \right]^2 + \frac{2\eta}{\sigma^2} \right\}^{\frac{1}{2}} < 0$$

Applying three boundary conditions, the solution to the dynamic programming problem is shown in Pindyck (1991):

$$F(V) = A V^{\beta} \qquad (6)$$

where

$$\beta = \frac{1}{2} - \frac{\eta - \delta}{\sigma^2} + \left\{ \left[\frac{\eta - \delta}{\sigma^2} - \frac{1}{2} \right]^2 + \frac{2\eta}{\sigma^2} \right\}^{\frac{1}{2}}$$

$$V^* = \frac{\beta \cdot C}{\beta - 1}$$

$$A = \frac{V^* - C}{V^{*\beta}} = \frac{(\beta - 1)^{\beta - 1}}{\beta^{\beta} C^{\beta - 1}}$$

As McDonald and Siegel (1985) point out, the solution derived above is equivalent to a call option. In other words, the value of the R&D project is analogous to a financial call option, and the decision of entering the product

market is the same as the decision of exercising such an option. It is easy to verify by simulation that the value of the R&D project, F(V), increases when the volatility, σ, increases, as does the critical value V*. In fact, under Black-Scholes framework for finite time period, t, if the market is complete, the value of the R&D investment becomes:

$$F(V) = VN(d_1) - Ce^{-rt}N(d_2)$$

where

$$d_1 = \frac{\ln(V/C) + (r + \sigma^2/2)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{\ln(V/C) + (r - \sigma^2/2)t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

N(x) is the cumulative probability distribution function for a variable that is normally distributed with a mean of zero and a standard deviation of 1.

Differentiate with respect to σ,

$$\frac{\partial F(V)}{\partial \sigma} = S\sqrt{t}N'(d_1) \geq 0$$

Thus greater uncertainty of the product market increases the value of a firm's investment on R&D. From simulations in option literatures, the value of R&D projects, F(V), and the exercising decision, V*, are highly sensitive to the volatility in project values, irrespective of investors' or managers' risk preferences, and irrespective of the extent to which the riskiness of V is correlated with the market[18].

B. Practical Concerns

There are some possible practical concerns when the basic model is applied to value a real R&D project.

1. Modeling Market Risk

In the basic model, the value of product market, V, is assumed to follow Geometric Brownian Motion. There are a variety of stochastic models that might exhibit different characteristics of value movements. Thorough

[17] Geometric Brownian Motion has the feature that once V reaches zero, it will stay at zero.

[18] See more details in Dixit and Pindyck (1994).

understanding of industry and technology is critical to determine the specification of stochastic process and to estimate related parameters. However, the exogenously specified stochastic process of the corresponding state valuable may not be realistic. The value of the product market depends on future prices of outputs and inputs, interest rate, and so on. These effects in turn can be explained by the underlying demand and behaviors of various markets. Hence fluctuations in V can be traced back to the uncertainty of these more basic variables. In addition, V is equal to market size multiplied by market price and hence can be viewed as the joint outcome of market and private risk. The size of the market may be affected by how strong the technology a firm developed and how well the product is accepted by customers.

2. Modeling Private Risk

There are at least three sources of private risk that is not taken into consideration in the basic model. First, the cost of R&D investment, I, may be uncertain. The total cost to complete R&D project is affected by how well the project goes and how strong the technology a firm developed. There might also be some other outside factors influencing the total cost. The uncertainty is resolved with the progress of R&D project. Besides, the cost of entering the product market including marketing expenditures and further development cost, C, may be uncertain. This uncertainty captures scientific or technical risk. The cost can be avoided by not exercising the growth option when the market turns out to be bad. Finally, the probability of success in R&D project may be uncertain. For pharmaceutics industry, this may be the probability of passing each phase of FDA test. For other industries, however, there might be some internal standards to decide whether the R&D project is successful or not. The outcome of R&D project and marketing process depends largely upon the resolution of those three sources of private risk.

3.Modeling Compound Options

The R&D project and marketing process can be modeled as a sequence of learning investment and abandonment options. In each period, a firm can reconsider whether to spend a predetermined amount for further development or

to abandon the R&D project right away. The reward for continuation is the next option. Each option contains the opportunity to make a similar decision in future periods and the possibility to gain the profits late in the product life cycle. This multiple period options can be handled by modeling the problem as compound options.

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